MIL-STD-188-112
31 AUGUST 1983

MILITARY STANDARD

SUBSYSTEM DESIGN AND ENGINEERING STANDARDS FOR COMMON LONG HAUL/TACTICAL CABLE AND WIRE COMMUNICATIONS

NO DELIVERABLE DATA

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THIS DOCUMENT CONTAINS 50 PAGES.

DEPARTMENT OF DEFENSE
Washington, D.C. 20301

Subsystem Design and Engineering Standards
For Common Long Haul/Tactical
Cable and Wire Communications

MIL-STD-188-112

1. This Military Standard is approved and mandatory for use by all Departments and Agencies of the Department of Defense. (See Appendix A.)

2. Beneficial comments (recommendations, additions, deletions) and any pertinent data which may be of use in improving this document should be addressed to:

Commander
U.S. Army Communications-Electronics Engineering Installation Agency
ATTN: CCC-CE-ES
Fort Huachuca, Arizona 85613

by using the self-addressed Standardization Document Improvement Proposal (DD Form 1426) appearing at the end of this document, or by letter.

FOREWORD

1. In the past, Military Standard 188 (MIL-STD-188), covering military communications system technical standards, has evolved from one document applicable to all military communications (MIL-STD-188, MIL-STD-188A, and MIL-STD-188B) to one applicable to tactical communications only (MIL-STD-188C).

2. The Defense Communications Agency (DCA) published DCA Circulars (DCAC) promulgating standards and criteria applicable to the Defense Communications System (DCS) and to the technical support of the National Military Command System (NMCS).

3. Standards for all military communications are now being published as part of a MIL-STD-188 series of documents. Military communications system technical standards are subdivided into common long haul/tactical standards (MIL-STD-188-100 series), tactical standards (MIL-STD-188-200 series), and long haul standards (MIL-STD-188-300 series).

4. This document contains technical standards and design objectives for common long haul and tactical symmetrical pair and coaxial cable communications subsystems. It supersedes MIL-STD-188-315, Standards for Long Haul Communications: Subsystem Design/Engineering and Equipment Technical Design Standards for Wire Systems.

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1. SCOPE

1.1 Purpose. This document provides mandatory system standards and suggests optional-design objectives to insure interoperability and to promote compatibility and commonality among long haul and tactical symmetrical-pair and coaxial cable transmission subsystems. This standard also establishes a level of performance considered necessary to satisfy a majority of users. This standard is intended to facilitate advances in technology rather than inhibit development.

1.2 Application. This standard is to be used in the design, engineering, and installation of new cable subsystems for long haul and tactical communications systems. New systems and those being modified or upgraded shall be made to conform to this standard. It is not the intent of this standard that existing systems be immediately converted to comply with its requirements. This standard pertains to the transmission media, and to equipment only as it affects the traffic. Telecommunications design parameters influence the functional integrity of telecommunication systems and their ability to efficiently interoperate with functionally similar Government and commercial systems. Therefore, relevant military standards in the MIL-STD-188 series will be mandatory for use within the Department of Defense (DoD).

1.3 System standards and design objectives. The parameters and other requirements specified in this document are mandatory subsystem standards if thi word "shall" is used in describing the subsystem's adherence to the parameter value under consideration. Nonmandatory design objectives are indicated by use of the Word "should" in connection with the parameter value under consideration. For a definition of the terms "system standard" and "design objective" see FED-STD-1037.

2. REFERENCED DOCUMENTS

2.1 Issues of documents. Unless otherwise specified the following standards and handbooks of the issue listed in that issue of the Department of Defense Index of Specifications and Standards (DODISS).specified in the solicitation form a Part of this standard to the extent specified herein.

STANDARDS:

FEDERAL:

FED-STD-1037	Glossary of Telecommunication Terms

MILITARY:

MIL-STD-188-100	Common Long Haul and Tactical Communication System Technical Standards
MIL-STD-188-124	Grounding, Bonding, and Shielding for Common Long Haul/Tactical Communication Systems

HANDBOOKS:

MILITARY:

MIL-HDBK-216	RF Transmissi on Lines and Fittings
MIL-HDBK-419	Grounding, Bonding, and Shielding for Electronic Equipment and Facilities

(Copies of specifications, standards, drawings, and publications required by contractors in connection with specific procurement functions should be obtained from the procuring activity or as directed by the contracting officer.)

2.2 Other publications. Not applicable.

3. DEFINITIONS

Definitions of most telecommunications terms used in this document are specified in FED-STD-1037. Following are definitions of terms peculiar to wire and cable subsystems which are not specified in FED-STD-1037. Appendix B comprises a list of abbreviations and acronyms and their meanings.

Dielectric strength. The maximum voltage a dielectric can withstand without rupturing; also called breakdown strength or insulating strength.

Field wire. A flexible insulated wire used in field telephone and field telegraph systems. WD-1 and WF-16 are types of field wire.

Shield. A screen or housing (usually a conductor) placed between the send and receive sides of wire pairs to reduce electric and magnetic fields between them. Also, the external conductor in a coaxial, twinaxial, or triaxial cable.

T1 carrier. A 24-channel digital data carrier with a rate of 1.644 megabits per second (Mb/s).

NOTE: T1C operates at 3.154 Mb/s and has 48 channels.

4. GENERAL REQUIREMENTS

4.1 Introduction. This standard deals with tactical and long haul wire and cable at a transmission medium for both digital and analog systems.

4.2 Transmission characteristics. Transmission characteristics shall be in accordance with MIL-STD-188-100 radio transmission subsystems, Parameters for analog service, Parameters for data service, and Transmission circuits. Though field wire may depart from these standards, its use in tactical communication systems is justified.

4.3 Grounding. Grounding. bonding, and shielding shall be in accordance with MIL-HDBK-419, Lightning protection for structures and Fault protective subsystem. High frequency cables shall be grounded in accordance with MIL-STD-188-124. Shield terminations of coaxial and other higher frequency cables. The objectives of grounding, bonding, and shielding are to protect personnel and communications equipment from hazardous voltages caused by lightning strikes, electrical power faults, and high-level electromagnetic radiation; and to keep circuit noise levels within acceptable limits under normal operating conditions.

4.4 Digital transmission. Cable systems often carry digital signals operating at a variety of transmission rates; for example, T1 carrier at 1.544 Mb/s; DCS pulse code modulation (PCM) time division multiplex (TDM) signals at 800ON b/s, where N is the number of PCM voice channels; and digital radio and multiplex acquisition (DRAMA) TDM signals in a hierarchy of rates (1.544, 3.2329, 6.4649, 9.696, 12.928 Mb/s). These digital signals are transmitted only over short cable distances; for example, 80 kilometers (km) (50 miles (mi)) or less for T1 carrier. Table I gives salient characteristics of T1 transmission.

TABLE I. T1 digital data rate characteristics.

Parameter	Value
Data rate	1.544 Mb/s
Pulse amplitude	3 volts (V)
Duty cycle	50 percent
Design frequency	772 kilohertz (kHz)
Channels	24

4.5 Crosstalk reduction in digital transmission. Four methods are used to reduce near-end crosstalk in digital transmission over paired cable:

a. A separate cable for each direction of transmission
b. Send and receive cable pairs separately bound within the same bidirectional cable.
c. An internal shield or screen separating transmit and receive pairs.
d. Low capacitance cable.

4.6 Mixing gages. In establishing new subsystems, avoid mixing wire gages. Where existing piant is to be used for a portion of a system, a mixture of gages is sometimes unavoidable. Even then, no more than two gages of wire should be joined in a symmetrical-pair cable run. Appendix E includes a table of wire gages in three systems: American Wire Gage (AWG), New British Standard (NBS)-also known as British Standard Wire Gage-(SWG), and Birmingham Wire Gage (BWG). Wire sizes in this document are given in American Wire Gage.

4.7 Lightning considerations. Lightning must be considered in some geograpnical areas. Certain cables, for example, foam-insulated cables, are more susceptible to lightning than others. (Refer to MIL-HDBK-419 for a complete discussion of lightning protection.)

4.8 Insulation considerations. Cable or wire must be able to withstand fluids or gases in the internal environment. (See Federal Supply Classification 6145 for detailed cable specifications pertaining to the effects of fluids and gases, wicking, corrosion, and temperature extremes.)

5. DETAILED REQUIREMENTS

5.1 Introduction. Section 6 is devoted to standards for electrical characteristics of 4-kHz multiple-pair circuits and coaxial, twinaxial, and triaxial cable for voice or data transmission.

5.2 Symmetrical-pair cable subsystems. These standards establish minimum performance requirements for a four wire nominal 4-kHz telephone-type circuit transmission multiple-pair line facility.

5.2.1 Electrical characteristics. The following standards apply to multiple-pair cables having metal shields and synthetic jackets. Appendix C comprises test methods for the following electrical characteristics.

> NOTE: Air-core cable placed without a dry gas flow system to provide a continuous positive pressurization can be expected to contain some degree of moisture. Moisture within the cable core can make the wires and cables unsuitable for voice frequency or carrier system circuits. Entrance of moisture causes increased mutual capacitance and attenuation. This transmission degradation should be taken into consideration when analyzing the performance of cables in aerial systems. Burying of air-core cable is not recommended.

5.2.1.1 Averaoe mutual capacitance. The average mutual capacitance of the pairs in any reel or multiple-pair cable shall be within the limits shown in table 11.

TABLE II. Average mutual Capacitance.

Number of Cable Pairs	Average Mutual Capacitance (μF/km)	(μF/mi)
Fewer than 6	0.052 ± 0.006	0.083 ± 0.010
6 to 17	0.052 ± 0.004	0.083 ± 0.007
18 or more	0.052 ± 0.002	0.083 ± 0.004

5.2.1.2 Capacitance unbalance, pair-to-pair. Pair-to-pair capacitance unbalance as measured on the completed cable at a frequency of 1000 hertz (Hz) ± 100 Hz shall not exceed the values listed in table III when corrected to 1-km or 1000-foot (ft) lengths.

TABLE III. Pair-to-pair capacitance unbalance.

Number of Cable Pairs	Maximum Individual Unbalance (pF/km)	Maximum Individual Unbalance (pF/1000 ft)	Root Mean Square (rms) Unbalance (pF/km)	Root Mean Square (rms) Unbalance (pF/1000 ft)
Fewer than 12	181	100	-----	-----
12 or more	-----	-----	45.3	25

NOTE: Pair-to-pair capacitance unbalance increases in proportion to the square root of cable length. It is measured in picofarads (pF).

5.2.1.3 Capacitance unbalance, pair-to-shield. Pair-to-shield capacitance unbalance as measured on the completed cable at a frequency of 1000 Hz +/- 100 Hz shall not exceed the values in table IV when corrected to 1-km or 1000-ft lengths. Pair-to-shield capacitance unbalance varies directly with cable length.

TABLE IV. Pair-to-shield capacitance unbalance.

Conductor Size AWG	Number of Cable Pairs	Maximum Individual Unbalance (pF/km)	Maximum Individual Unbalance (pF/1000 ft)	rms Unbalance (pF/km)	rms Unbalance (pF/1000 ft)
19, 22, 24	Fewer than 12	-----	-----	984	300
	12 or more	410	125	-----	-----
26	Fewer than 12	328	100	1640	500
	12 or more	328	100	1640	500

5.2.1.4 Capacitance unbalance, pair-to-ground. The maximum average pair-to-ground capacitance Unbalance shall not exceed 656 pF/kM 1200 pF/1000 ft). The individual pair-to-ground capacitance Unbalance shall not exceed 2625 pF/km (800 pF/1000 ft). Pair-to-ground capacitance unbalance varies directly with cable length.

5.2.1.5 Crosstalk loss. The rms output-to-output, far-end crosstalk coupling loss as measured on the complete cable at a frequency of 150 Hz shall be greater than 67.8 decibels ?dB)/km (73 dB/1000 ft) for cable with 6 or more pairs. The rms value shall be based on the combined total of all adjacent and alternate pair combinations within the same layer and center-to first-layer pair combinations. The minimum individual far-end crosstalk coupling loss shall be 57.8 dB/km (63 dB/1000 ft).

5.2.1.6 Mutual conductance. Mutual conductance of any cable pair, shall not exceed 1.2 micromhos/km (2 micromhos/mi).

5.2.1.7 Dielectric strength (voltage withstand). The insulation between the shield and any Conductor, and the Insulation between conductors, shall withstand for 3 seconds a direct current (dc) voltage not less than that shown in table V.

TABLE V. Insulation 3-second dc voltage withstand .

AWG Number	19	22	24	26
Conductor-to-conductor	4,500	3,600	3,000	2,400
Conductor-to-shield	10,000	10,000	10,000	10,000

5.2.1.8 Insulation resistance . Each insulated conductor shall have an insulation resistance of not less than 16,000 megohm-km (10,000 megohm-mi).

5.2.1.9 Conductor resistance . The dc resistance of any conductor shall not exceed the valies given in table VI when corrected to 1-km or 1000-ft lengths measured at or corrected to 200 Celsius (C) (68 Fahrenheit (F)).

TABLE VI. Maximum conductor resistance

Conductor Size (AWG)	Maximum Conductor Resistance (ohms/km)	(ohms/1,000 ft)	Maximum Average Conductor Resistance (ohms/km)	(ohms/1,000 ft)
19	28.5	8.7	27.6	8.4
22	57.1	17.4	55.4	16.9
24	90.2	27.5	87.6	26.7
26	144.4	44.0	141.1	43.0

5.2.1.10 Resistance unbalance . The difference in dc resistance between two conductors of a pair shall nof exceed the values listed in table VII when corrected to 1-km or 1000-ft lengths. Resistance is proportional to the cable length. For composite cables, a separate average shall be determined for each gage which shall meet the requirements of table VII. The resistance unbalance between conductors shall be completely random with respect to direction of the unbalance; that is, the resistance of one conductor shall not be consistently higher with respect to another conductor.

TABLE VII. Maximum resistance unbalance .

Conductor Size (AWG)	Average for Any Reel (ohms/km)	(ohms/1000 ft)	Maximum Individual Pair (ohms/km)	(ohms/1000 ft)
19	0.66	0.2	1.97	0.6
22	1.31	0.4	3.94	1.2
24	1.97	0.6	5.91	1.8
26	2.95	0.9	7.87	2.4

5.2.1.11 Crosses, shorts, and grounds . . Each reel of cable shall be free from crosses, shorts, and grounds (respectively, insulation fault between a conductor of one pair and a conductor of another pair; between a conductor and the shield; and between the shield and ground) when tested with dc voltages listed in table VIII.

TABLE VIII. DC testing voltages .

Conductor Size (AWG)	dc Voltage (kilovolts (kV))
19	4.5
22	3.6
24	3.0
26	2.4

5.2.1.12 Shield continuity . The shield shall be continuous and uniform over the entire length ot tne Cable.

5.2.2 Frequency response . Attenuation as a function of frequency should agree with the nominal values shown in figure I for AWG numbers 19, 22, 24, and 26.

NOTE: Attenuation of mixed gage systems can be calculated as in the following example. At a frequency of 200 kHz, 22 AWG cable has an attenuation of 11 dB/mf, and 19 AWG cable has an attenuation of 8 dB/mi (see figure 1). A run of 2 miles of 22 AWG and 3 miles of 19 AWG cable would have a total attenuation of 46 dB, that is 22 dB (2 mi x 11 dB/mi) added to 24 dB (3 mi x 8 dB/mi). When measuring attenuation, the cable is terminated in its characteristic impedance.

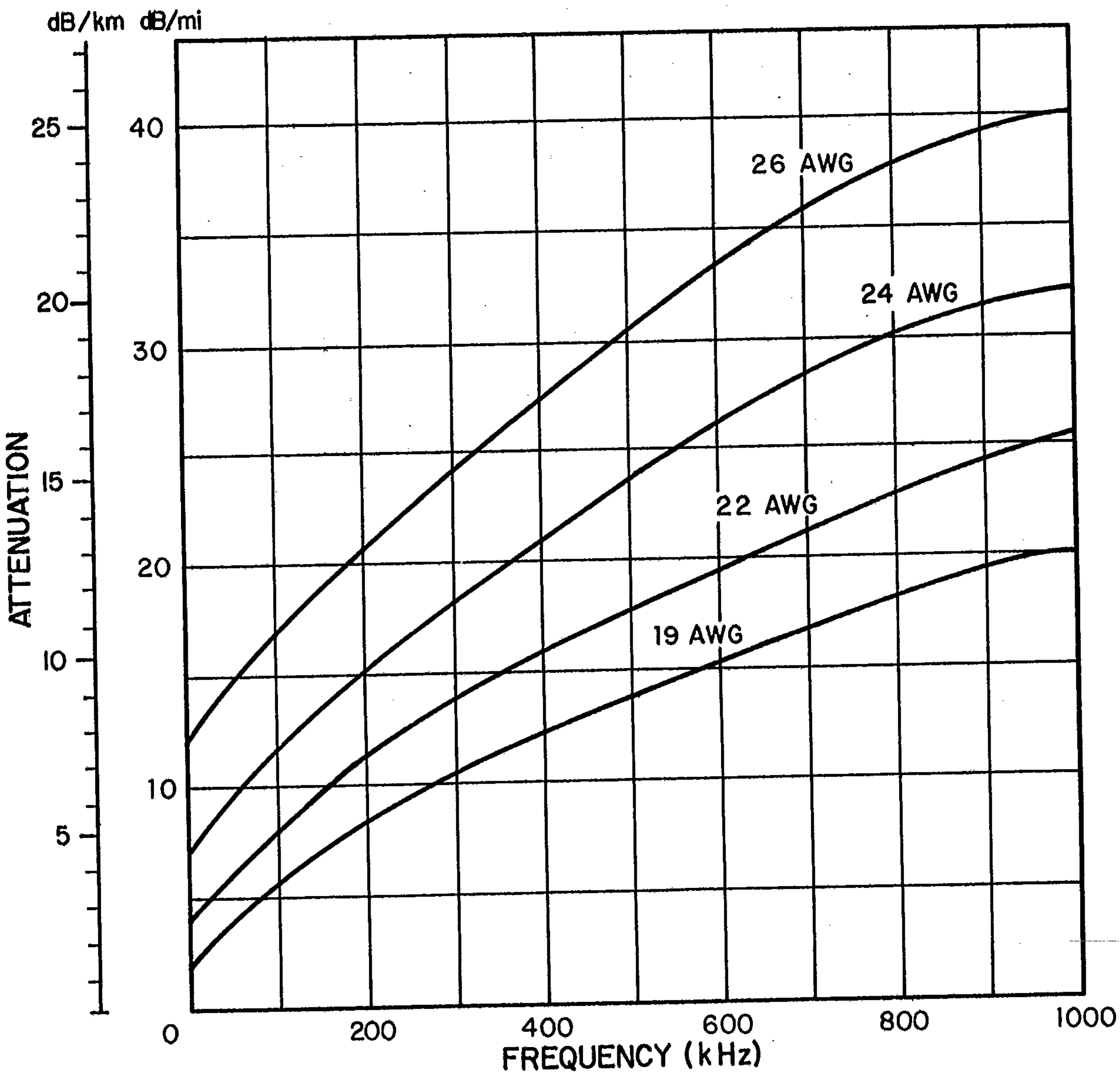
dB/km dB/mi
25
20
15
10
5
40
30
20
10
ATTENUATION
26 AWG
24 AWG
22 AWG
19 AWG
0
200
400
600
800
1000
FREQUENCY (kHz)

FIGURE 1

5.3 Internally screened multipair cable. Internally screened cable is generally used in high speed data transmission systems. The screen minimizes near-end crosstalk by separating the cable pairs into two identical sections.

5.3.1 Near-end crosstalk (NEXT). The internal screen shall reduce near-end crosstalk to within the values of the curve in figure 2. This reduction shall be accomplished without affecting mutual capacitance (in the event part of the pairs are used for loaded voice frequency transmission) or other electrical characteristics.

5.3.2 Dielectric strength. Presence of the internal screen should not degrade dielectric strength integrity of cable pairs.

5.3.3 Carrier frequency attenuation. Carrier frequency attenuation in internally screened symmetrical pair cables should be within the nominal limits shown in fig 4 (For T1 carrier, repeater spacing shall be of a distance which yields a maximum of 32 dB between repeaters or between repeaters and receivers in order to maintain adequate signal-to-noise ratios.)

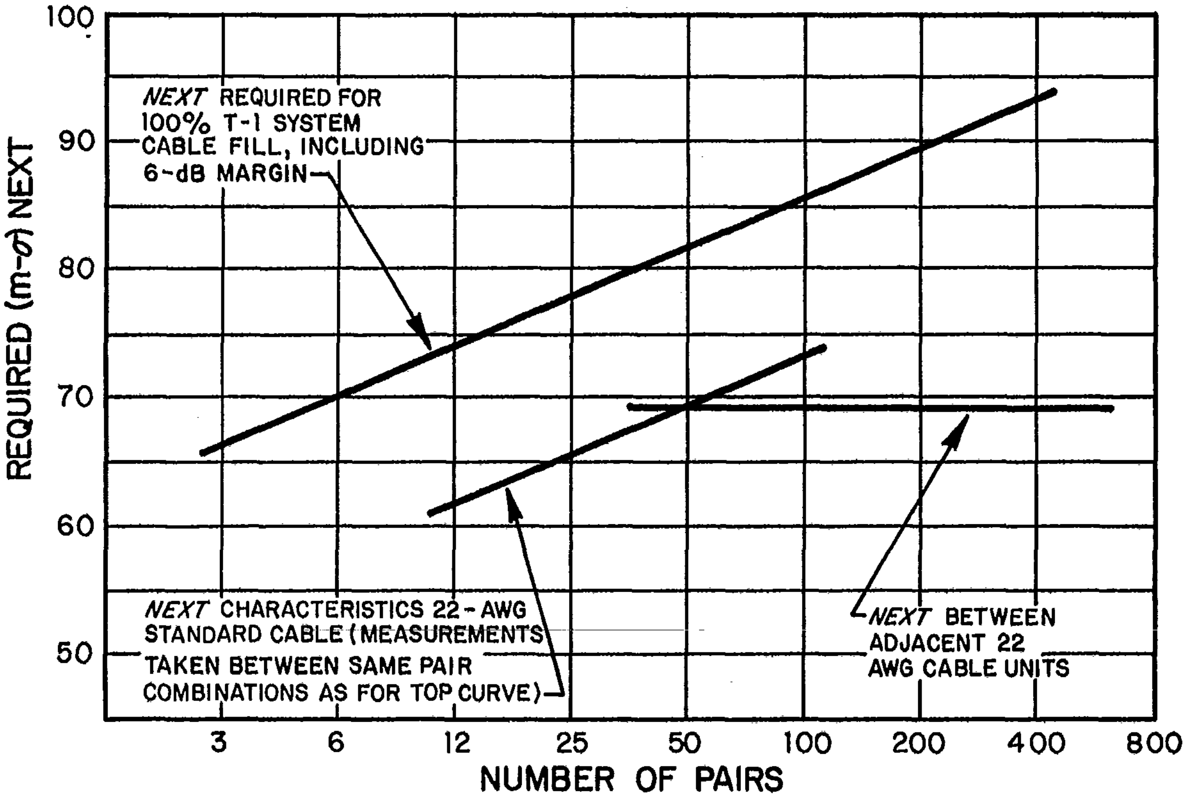
NEXT REQUIRED FOR 100% T-1 SYSTEM CABLE FILL, INCLUDING 6-dB MARGIN
NEXT CHARACTERISTICS 22-AWG STANDARD CABLE (MEASUREMENTS TAKEN BETWEEN SAME PAIR COMBINATIONS AS FOR TOP CURVE)
NEXT BETWEEN ADJACENT 22 AWG CABLE UNITS
REQUIRED (m-σ) NEXT
100
90
80
70
60
50
3
6
12
25
50
100
200
400
800
NUMBER OF PAIRS

FIGURE 2.

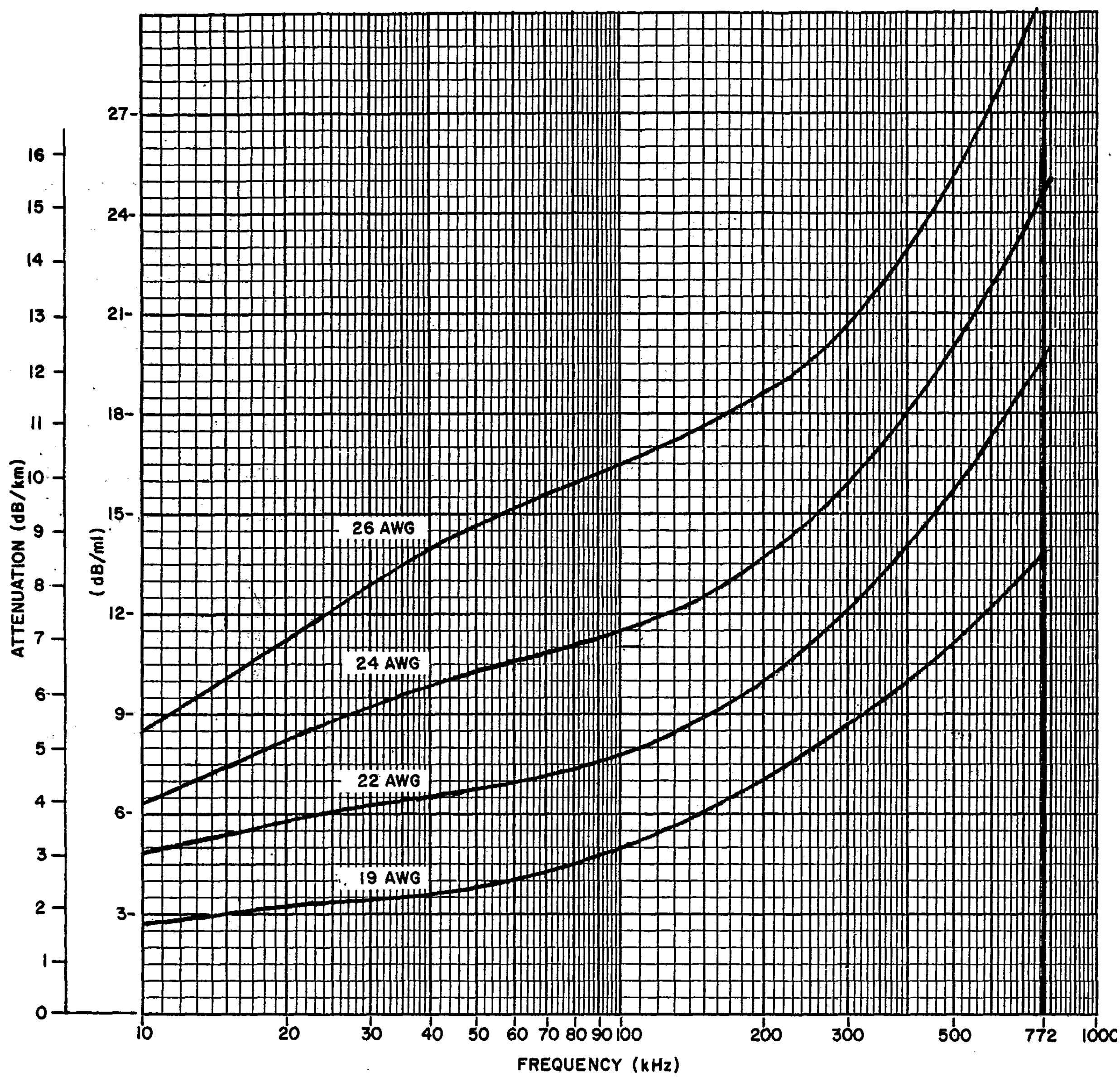

FIGURE 3. Carrier frequency attenuation .

5.3.4 Repeater spacing for digital transmission. During the early development of cable repeaters for PCM transmission (specifically TI carrier), the repeaters were designed for installation at the same intervals as the already existing loading coils in 22-gage, paper-insulated, 0.083lpF cable. By this narrow definition, they provided a gain of 35 dB; hence, a convention arose that the maximum repeater spacing would be a distance that yielded a maximum attenuation of 35 dB. This repeater spacing is not a mandatory standard.

5.4 Low-capacitance cable. Depending upon application, low-capacitance cable ranging from 19.9 to 39.7 nanofarads/km (nF/km) (32 to 64 nF/mi) can reduce near-end crosstalk in digital transmission.

5.5 Coaxial, twinaxial, and triaxial cable subsystems. Coaxial; triaxial; and shielded, two-conauctor, twisted-pair (twinaxial) cable subsystems are used in tactical and long haul communications systems for the transmission of baseband, video, and radio frequencies. In general, larger cables have lower dc resistance, attenuation, and return loss; higher dielectric strength; and similar characteristic impedance, capacitance, and velocity of propagation. The nominal electrical characteristics of selected cables are shown in table IX. Cables shall meet the following standards given in MIL-STD-188-100: Parameters for analog service, Parameters for data service, and Transmission circuits. Characteristics of radio frequency cable are listed In MIL-HDBK-2I6.

5.5.1 Frequency response. Typical cables have attenuation-versus-frequency characteristics as shown in table IX.

5.5.2 Total channel noise. Noise accumulation as a function of cable system length shall not exceed 1.62 picowatts psophometrically weighted (pWp) (rms)/km (2.6 pWp (rms)/mi) measured over the bandwidth of a nominal Voice channel (300 to 3400 Hz).

TABLE IX. Electrical data for selected cable

	RG-58/U	RG-59/U	RG-108/U	TWC 78-2	TWC 124-2	CX11230
Nominal impedance ohms	50	75	78	78	124	60 (below 400 kHz), 55 (above 400 kHz)
Nominal capacitance pF/m	93.5	68.9	80.4	64.6	40.7	----
(pF/ft)	(28.5)	(21.0)	(24.5)	(19.7)	(12.4)	----
DC loop resistance ohms/km	---	---	---	62.3	196.8	55
(ohms/1000 ft)	---	---	---	(19.0)	(60.0)	(16.7)
Maximum operating voltage (Vrms)	1900	2300	1000	1000	1000	----

Nominal attenuation
dB/100 m
(dB/100 ft)

Frequency (kHz)						
10	4.6	3.6	7.5	5.2	5.2	----
	(1.4)	(1.1)	(2.3)	(1.6)	(1.6)	----
50	4.4	8.9	17.1	17.0	11.8	----
	(1.3)	(2.7)	(5.2)	(5.2)	(3.6)	----
100	17.4	13.1	24.6	----	----	0.53
	(5.3)	(4.0)	(7.5)	----	----	(0.161)
400	37.7	27.9	52.5	----	----	----
	(11.5)	(8.5)	(16.0)	----	----	----

NOTE: The above values are typical, but some variations will appear between manufacturers. Blanks represent information not applicable.

5.5.3 Repeater section. Repeater section planning length is determined not only bv cable characteristics, but by factors external to the cable such as transmitter power and receiver noise figure. The existence of external factors precludes the standardization of planning lengths. Procedures for calculating planning lengths at 200 C (68 F) and other temperatures are given in Appendix D, along with sample calculations.

5.5.4 Crosstalk. The highest value of near-end or far-end crosstalk at the lowest Transmitted intelligence frequency shall be at least 55 dB below signal level.

5.5.5 Electrical characteristics. Electrical characteristics for typical coaxial cables follow.

5.5.5.1 Resistance. The dc loop resistance for cables measured over 30.5 meter (m) (100 ft) lengths at 20 C (68 F) is given in table IX for selected cables.

5.5.5.2 Capacitance. The capacitance for selected cables is given in table IX.

5.5.5.3 Impedance. The real component of the impedance of typical coaxial cables terminated in a nonreactive load and measured at a frequency of 1 megahertz (MHz) shall be one of the following values:

50 +/- 2 ohms
60 +/- 2 ohms
75 +/- 2 ohms
78 +/- 2 ohms (balanced twin-conductor)
95 +/- 2 ohms
124 +/- 2 ohms (balanced twin-conductor)

5.5.5.4 Return loss. The return loss shall not be less than 24 dB against a resistance equal to nominal impedance over the useful frequency range of the cable.

5.5.5.5 Maximum operating voltage. Maximum operating voltage that can be withstood by typical cables is given in table IX.

5.5.6 Cable characteristics for video transmission.

5.5.6.1 Impedance. The impedance shall be 75 ± 2 ohms at video input and output terminals.

5.5.6.2 Return loss. See 5.4.6.4.

6.6.6.3 Attenuation distortion. Attenuation distortion shall not exceed the following values:

+/- 1 dB up to 2 megahertz (MHz)
+/- 2 dB from 2 MHz to 4 MHz, except +/- 1 dB at 3.58 MHz (colorburst frequency)
+/- 3 dB from 4 MHz to 5 Mhz

5.5.6.4 Phase deviation. The phase deviation between 30 Hz and 4 MHz shall not exceed 5 degrees (equivalent to 0.004 microseconds) time delay at 3.58 MHz).

5.5.6.5 Group delay distortion. The spread of the variation in group delay between 2 mhz and 4 mhz shall not exceed 4 microseconds, and between 4 MHz and 5 MHz shall not exceed 1 microsecond. The change of group delay in 100 kHz intervals shall be less than 0.1 microseconds.

Custodians:

Army - CR
Navy - EC

Air Force - 90
Defense Communications Agency - DC

Review activities:

Army - CR
Navy - OM
DoD/NASA - TT

User activities:

Navy - YD
Air Force - 02
DoD/NASA - NS

Preparing activity:

Army - SC

Civil Agency Coordinating Interest:
National Communications System - NCS

(Project SLHC-1120)

APPENDIX A

MEMORANDUM FROM THE ASSISTANT SECRETARY OF DEFENSE FOR COMMUNICATIONS, COMMAND, CONTROL AND INTELLIGENCE, 10 MAY 1977; SUBJECT: MANDATORY USE OF MILITARY STANDARDS IN THE 188 SERIES.

This appendix contains information related to MIL-STD-188-112. Appendix A is a mandatory part of this standard.

ASSISTANT SECRETARY OF DEFENSE
WASHINGTON, D. C. 20301

10 MAY 1977

COMMUNICATIONS, COMMAND,
CONTROL, AND INTELLIGENCE

MEMORANDUM FOR Assistant -Secretary of the Army (I&L)
Assistant Secretary of the Navy (I&L)
Assistant Secretary of the Air Force (I&L)
Commandant of the Marine Corps
Director, Defense Communications Agency
Director, National Security Agency

SUBJECT: Mandatory use of military standards in the 188 Series

On January 3, 1972, the Assistant Secretary of Defense (I&L) found it necessary to make a significant change in the DoD Standardization Manual 412O.3M because of recurring misapplications of military standards in general. The consequence of the change is that military standards as a general rule are now cited as "approved for use" rather than "mandatory for use" in the Departznent of Defense.

This deference to the judgment of the designing and procuring agencies is clearly appropriate to standards dealing with process, component ruggedness and reliability, paint finishes, and the like. It is clearly not appropriate to standards such as those in the MILSTD 188 series which address telecommunication desig n parameters. These influence the functional integrity of telecommunication systems and their ability to efficiently interoperate with other functionally similar Government and commercial systems. Therefore, relevant military standards in the 188 series will continue to be mandatory for use within the Depart ment of Defense.

To minimize the probability of misapplication of these standards, it is incumbent upon the developers of the MILSTD 188 series to insure that each standard is not only essential but of uniformly high quality, clear and concise as to application, and wherever possible compatible with existing or proposed national, international and Federal telecommunica tion standards. It is also incumbent upon the users of these standards to cite in their procurement specifications only those standards which are clearly necessary to the proper functioning of the device or systems over its projected lifetime.

This direction is in consonance with the recommendations made by the Director, Defense Materiel Specifications and Standards Office, in his letter of March 4, 1977, which was addressed to the U.S . Army Elec tronics Command.

Gerald P. Dinneen

Gerald P. Dinneen

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APPENDIX B

ABBREVIATIONS AND ACRONYMS

10. GENERAL

10.1 Scope. This appendix contains a list of abbreviations and acronyms used in MIL-STD-188-112.

10.2 Application. This appendix is a nonmandatory part of MIL-STD-188-112.

AWG	American Wire Gage
b/s	bits per second
BWG	Birmingham Wire Gage
c	Celsius
dB	decibel
dBm0	decibels (noise power) referred to one millivolt at zero transmission level point
dc	direct current
DCA	Defense Communications Agency
DCAC	Defense Communications Agency Circular
DCS	Defense Commun ications System
DoD	Department of Defense
DODISS	Department of Defense Index of Specifications and Standards
DRAMA	Digital Radio and Multiplex Acquisition
F	Fahrenheit
FSC	Federal Supply Class
ft	feet
Hz	hertz
kHz	kilohertz
km	kilometer
kV	kilovolt
m	meter
Mb/s	megabits per second
MHz	megahertz
mi	mile
µF	microfarad
µs	microseconds
NBS	New British Standard
NEXT	near-end crosstalk
nF	nanofarad
NMCS	National Military Command System
PCM	pulse code modulation
pF	picofarad
pwp	picowatts psop hometrically weighted
RG/U	radio guide, universal
rms	root mean square
SWG	British Standard Wire Gage
TDM	time-division multiplex

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APPENDIX C

TEST METHODS

CONTENTS

FIGURES

APPENDIX C
TEST METHODS

10. GENERAL

10.1 Scope. This appendix provides general techniques and methods for measuring values for the performance parameters of wire and cable specified in section 5. This section provides information to further the understanding of parameters included in the standard. When using these test techniques, care must be observed in selecting test equipment so satisfactory results are obtained, and caution must be taken to insure the safety of personnel and equipment involved.

10.2 Application. This appendix discusses test methods common to wire and cable transmission in long haul or tactical communications systems. The discussion treats general methods of testing rather than step-by-step procedures. This appendix is a nonmandatory part of MIL-STD-188-112.

20. REFERENCED DOCUMENTS

20.1 Issues of documents. Unless otherwise specified, the following standard of the issue listed in that issue of the Department of Defense Index of Specifications and Standards (DODISS) specified in the solicitation forms a part of this standard to the extent specified herein.

STANDARDS

MILITARY

MIL-STD-188-100	Common Long Haul and Tactical Communication System Technical Standards

20.2 Other publications. The following document forms a part of this standard to the extent specified herein.

ANSI C8.47-1977	Communications Cables, Polyolefin-Insulated, Thermoplastic-jacketed

(Application for copies should be addressed to American National Standards Institute, 1450 Broadway, New York, NY 10016.)

30. TEST METHODS

30.1 Total channel noise. (Refer to 5.5.2.) Total channel noise in cable systems is made up of random thermal and crosstalk components. (This discussion does not include impulse noise due to lightning, switching transients, and other sporadic phenomena, since the concern of the standard here is "continuous" noise.) A measurement of noise in nonmultiplexed voice channels employs a Western Electric 3A or equal noise-measuring set. The measurement of noise in multiplexed voice channels employs a white noise test set. In using a white noise test set to measure total channel noise in voice frequency channels, the transmitter of the test set produces a wideband noise spectrum that simulates busy-hour traffic conditions. Thus, it simulates the combination of thermal and crosstalk (nonintelligible only) components. A notch filter prevents the transmission of the simulated noise in a band representative of a nominal voice channel. At the receiving end of the transmission-system, the receive portion of the test set provides a measurement of the noise present in the notch-filtered band.

30.2 Conductor resistance and resistance unbalance. (Refer to 5.2.1.9, 5.2.1.10, and 5.5.14) The resistance of the conductor is measured in one of two ways: by a Wheatstone bridge, in which a resistance is measured in direct comparison with a standard resistance; or by a Varley loop, which gives the difference in resistance between two wires in a loop. The Varley loop is a variation of the Wheatstone bridge.

30.2.1 Wheatstone bridge method. In the Wheatstone bridge method, the length of conductor should be known to an accuracy of 0.2 percent. Leads used to connect the measuring bridge to the cable facility being measured should be short-circuited at the far end and their resistance measured. The result should then be subtracted from the total value obtained in the test.

30.2.2 Varley loop method. This method is an alternative use of the Wheatstone bridge in which only one end of the conductor to be measured is near the test unit and the other end is at a distance, requiring the use of an additional conductor of unknown resistance. Two measurements are necessary (figures C-1 and C-2) before a result can be obtained. Identify the conductor at the two points between which the resistance is to be measured, and identify a spare conductor between the same two points. Strap the conductors together at the far end (see figure C-1) and connect the near ends to the resistance bridge as shown in the figure. Read the resistance in the customary fashion, recording the figure as RI, realizing this is not in itself the desired information. The shorting strap is now connected as in figure C-2 and the near connections are also changed as shown in the figure. The resistance is again read, and recorded as R2. The desired resistance, Rx, is calculated from the following formula:

$$Rx = A\ (R2 - Rl)/(A + B)$$

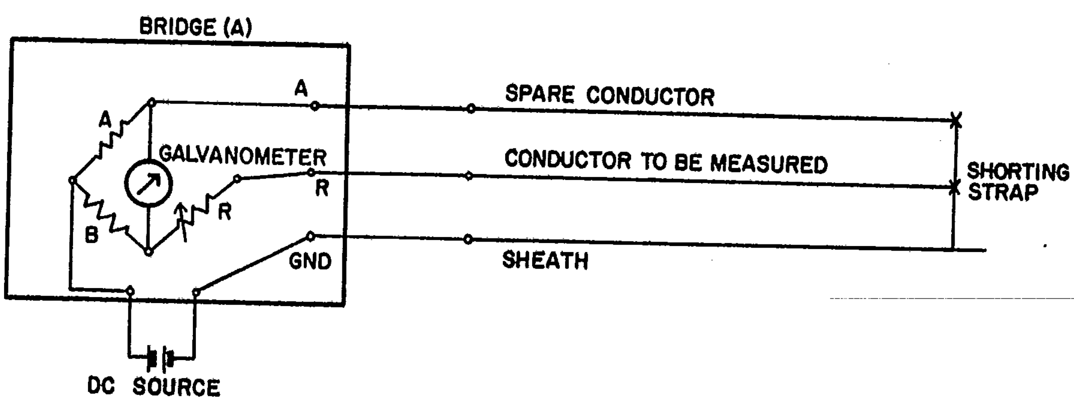


FIGURE C-1. First measurement of conductor resistance, Varley loop method.

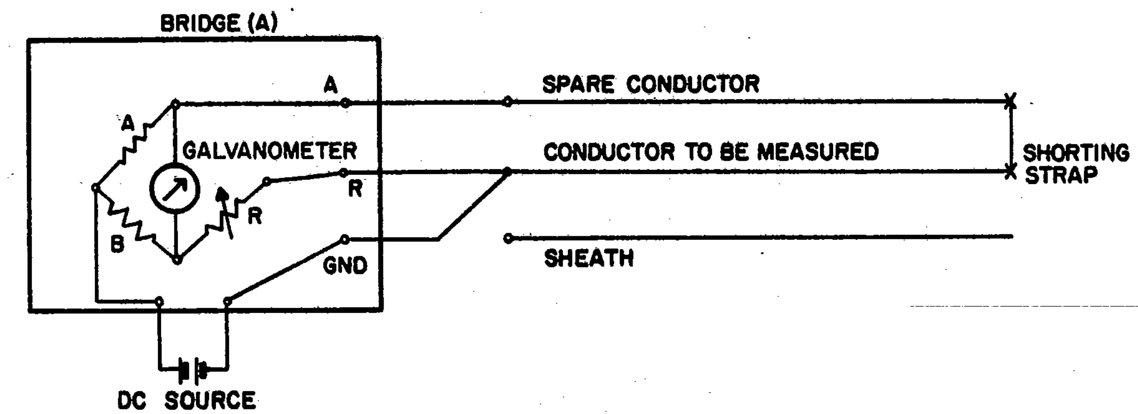


FIGURE C-2. Second measurement of conductor resistance, Varley loop method.

A = value of A arm

B = value of B arm

R1 = value of R. first measurement

R2 = value of R, second measurement

30.3 Mutual capacitance and capacitance unbalance. (Refer to 5.2.1.2, 5.2.1.3, 5.2.1.4, and 5.5.5.2.) This test measures effective capacitance between two wires of a pair; and capacitance unbalance between pairs, or between pairs and shield. The capacitance between two conductors is the ratio between the charge transferred from one conductor to the other, and the resultant difference in the potentials of the two conductors when insulated from each other and from all other conductors. The test is performed with an impedance bridge with internal 1000 hertz (Hz) ± 100 Hz oscillator and detector function. Capacitance measurements should be limited to single-reel lengths of cable and made at, or corrected to 20 Celsius (C) (68 Fahrenheit (F)). Pairs not under immediate test should be grounded to the sheath. Connecting leads should be shorted to themselves at the far end from the bridge and the amount of lead capacitance measured, and subtracted from the overall capacitance measured.

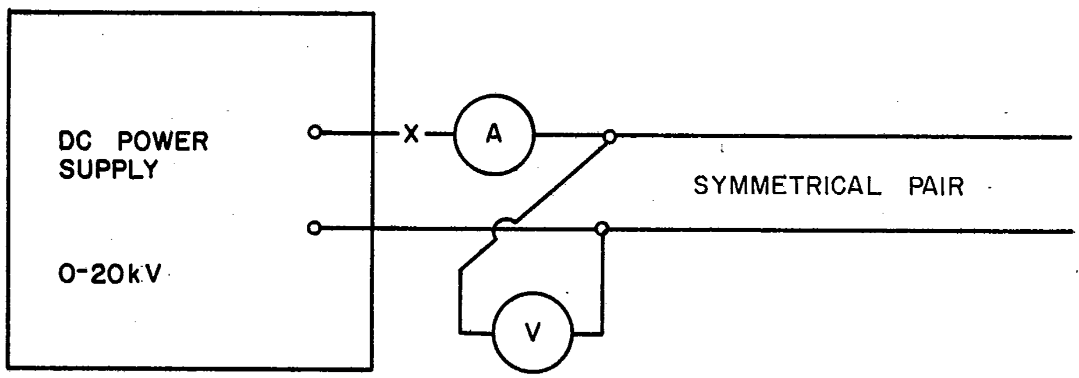
30.4 Dielectric strength (voltage withstand). (Refer to 5.2.1.7 and 5.3.2.) The following method is used for the measurement of dielectric voltage withstand between conductors of a cable, between conductors and a cable shield, and between inner and outer conductors of a coaxial cable. Voltage is applied between conductors or between conductors and shield until dielectric breakdown occurs, or the required voltage withstand duration is reached.

30.4.1 Conductor-to-conductor voltage withstand. A direct current (dc) power supply, circuit breaker, and ammeter are connected in series, and a voltmeter in parallel as shown in figure C-3. The voltage is increased until the required voltage is reached or dielectric rupture causes a breakdown.

30.4.2 Conductor-to-shield voltage withstand. The apparatus is connected as shown in figure C-4 and the test performed as described In 30.4.1 above.

30.5 Return loss measurement with time domain reflectometer (TDR). (Refer to 5.5.5.4.) Return loss can be measured with a TOR. The cable under test should be of sufficient length to exhibit at least 3 dB attenuation. Suitable connectors are attached to the ends of the cable under test. The TDR should be capable of producing a step function with a rise time of not more that 150 picoseconds.

30.6 Impedance. (Refer to 5.5.5.3. and 5.5.6.1.) In testing transmission systems, input and output impedances are measured at both ends of the cable. Measurements may also be required on individual items of equipment. The method uses a standard alternating current (ac) bridge to measure the impedances. Normally, the impedance of transmission system inputs and



NOTE: A = Ammeter
X = Circuit Breaker
V = Voltmeter

FIGURE C-3. Dielectric voltage withstand, conductor-to-conductor, symmetric-pair cable.

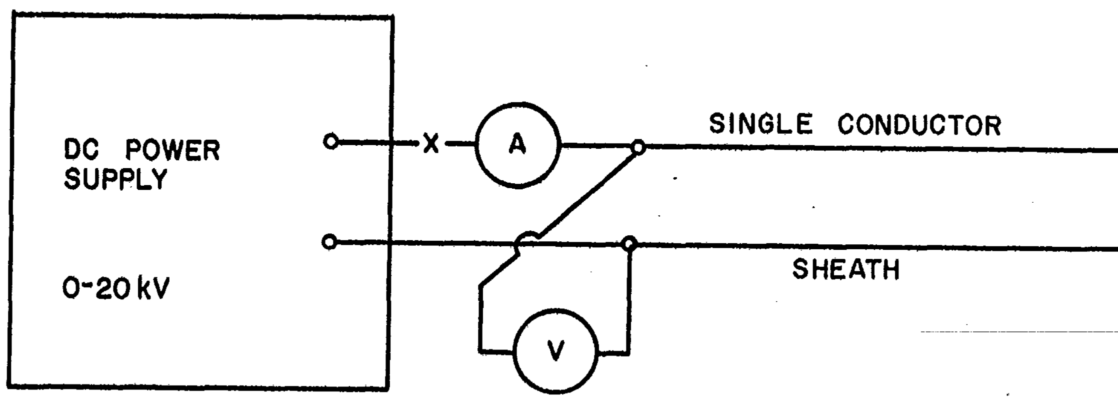


FIGURE C-4. Dielectric voltage withstand, conductor-to-sheath, Asymmetrical-pair or coaxial cable.

outputs should be measured at the test tone level normally used at that point of the system. Two kinds of ac bridges may be used. See MIL-STD-188-100, Common Test Methods, impedance,

30.7 Crosstalk. (Refer to 5.2.1.5 and 5.5.4.) Crosstalk is indicated when, in two adjacent signal-carrying channels, signals from one channel may be detected in the other. Crosstalk is evidenced as near-end and far-end crosstalk, depending on which end contains the interference-producing mechanism. A signal is applied to a "disturbing" channel, at a level which generally should not exceed zero dBmO at the zero transmission level point, then the crosstalk level on the disturbed channel is measured. Near-end crosstalk is measured at the end nearest to the source of the disturbing signal (i.e., at the sending station) while far-end crosstalk is measured at the far end of the channel ,i.e., at the receiving station). Crosstalk attenuation is measured as the ratio, in decibels, of the power delivered by the source into a disturbing channel to the power received at the point of measurement in the disturbed channel. See MIL-STD-188-100, Common Test-Methods, Crosstalk. The root mean square (rms) output-to-output far-end crosstalk-loss is to be.measured. The rms calculation is based on the combined total of all adjacent and alternate pair combinations within the same layer and center to first-layer pair.combinations. The rms crosstalk voltage ratio, in decibels, is the rms crosstalk loss. See ANSI C8.47-1977, Crosstalk loss,

30.8 Frequency response (attenuation versus frequency). (Refer to 5.2.2 and 5.3.3) Any signal carrying intelligence extends over a band of frequencies. Real channels discriminate against some frequencies while favoring other frequencies. The resulting change in the signal is known as frequency-versus-amplitude distortion, frequency response, or attenuation distortion. To test for frequency response, the channel input at the sending station is terminated in a signal generator of appropriate frequency range, whose output.impedance matches the nominal channel impedance. The channel output at the receiving station is terminated in a level measuring set whose input impedance matches the channel impedance. A variable frequency signal is transmitted over the channel under test, and measurements are recorded at a number of selected frequencies.

30.9 Crosses, shorts, and grounds. (Refer to 5.2.1.11.) Voltage tests are made on conductors. The Insulation between each conductor and all other conductors together should be capable of withstanding the specified dc voltage for 3 seconds. Each conductor is connected in turn to the voltage source, while.all other conductors and the shield are grounded. The insulation should withstand the specified value of voltage (table VIII) for the specified time in each case.

30.10 Insulation resistance. (Refer to 5.2.1.8.) Each insulated conductor is to be measured with all other conductors and the shield grounded. The measurements are made with a dc potential of not less than 100 volts (V) or more than 550 V applied for 1 minute.

30.11 Mutual conductance. (Refer to 5.2.1.6.) Mutual conductance is measured by connecting a high-resistance ohmmeter between the two conductors of a cable pair, with all other conductors of the cable connected to ground. The ohmmeter reading, in megohms, is converted to micromhos by taking the reciprocal.

40. ABBREVIATIONS

ac	alternating current
C	Celsius
dB	decibels
dBmO	decibels (noise power) referred to one milliwatt at zero transmission level point
dc	direct current
F	Fahrenheit
Hz	hertz
rms	root mean square
TOR	time domain reflectometer
V	volt

APPENDIX D

TEMPERATURE CORRECTION FORMULAS FOR ATTENUATION, RESISTANCE, AND REPEATER SPACING

CONTENTS

TABLES

APPENDIX D

TEMPERATURE CORRECTION FORMULAS FOR ATTENUATION* RESISTANCE, AND REPEATER SPACING

10. GENERAL

10.1 Scope. The formulas in this appendix should aid the user in determining increases in attenuation and resistance as affected by increases in temperature.

10.2 Application. This appendix contains tutorial information in support of MIL-STD-IB8-112. It is a nonmandatory part of this standard.

20. TEMPERATURE CORRECTION, SYMMETRICAL-PAIR CABLE

20.1 Direct current (dc) resistance correction. The dc Resistance change in paired cable is approximately 2 percent change for each 5 ^{o} Celsius (C) change in temperature (approximately 1.1 percent change for each 5 ^{o} Fahrenheit (F) change in temperature).

Celsius	Fahrenheit
$R_{tc} = R_{20}[1 + 0.004(T_c - 20)]$	$R_{tf} = R_{68}[1 + 0.0022(T_f - 68)]$

where:

R_{tc} = resistance at new temperature, in degrees Celsius	R_{tf} = resistance at new temperature, in degrees Fahrenheit
R_{20} = a resistance at 20 ^{o}C	R_{68} = a resistance at 69 ^{o}F
T_c = new temperature, in degrees Celsius	T_f = new temperature, in degrees Fahrenheit

20.2 Alternating current (ac) resistance and attenuation correction. The following formulas alply to copper cables with average mutual capacitance of 0.062 microfarads/kilometer (0.083 microfarads/mile).

Celsius	Fahrenheit
Resistance: $R_{tc} = R_{20}[1 + C_{tc}(T_c - 20)]$	Resistance: $R_{tf} = R_{68}[1 + C_{tf}(T_f - 68)]$
Attenuation: $A_{tc} = A_{20}[1 + C_{tc}(Tc - 20)]$	Attenuation: $A_{tf} = A_{20}[1 + C_{tf}(T_f - 68)]$
where:	where:
R_{tc} = resistance at new temperature, in degrees Celsius	R_{tf} = resistance at new temperature, in degrees Fahrenhei t
T_c = new temperature, in degrees Celsius	T_f = new temperature, in degrees Fahrenheit

C_{tc} = temperature correction factor (See table D-I.)

A_{tc} = attenuation at new temperature, decibels (dB)

R_{20} = resistance at 20 ^{o}C, in ohms

A_{20} = attenuation at 20 ^{o}C, in dB.

C_{tf} = temperature correction factor (See table D-I.)

A_{tf} = attenuation at new temperature dB

R_{68} = resistance at 68 ^{o}F, in ohms

A_{68} = attenuation at 68 ^{o}F, in dB

NOTE: An unknown resistance or attenuation can be calculated from a known quantity at a reference temperature other than 20 ^{o}C (6^{o}F) using these formulas with minor changes. The known resistance will be substituted for R20 (R68); the alternate reference temperature will be substituted for 20C (68F).

TABLE D-I. Temperature correction factor (C_t) x 10^{-3}.

FREQUENCY (kHz)		19 AWG	22 AWG	24 AWG	26 AWG
10	°C	3.3	3.9	4.3	4.6
	(°F)	(6.0)	(7.0)	(7.8)	(8.3)
50	°C	3.3	3.0	3.1	3.4
	(°F)	(5.9)	(5.4)	(5.6)	(6.1)
100	°C	3.9	3.3	3.0	3.1
	(°F)	(7.0)	(5.9)	(5.5)	(5.5)
200	°C	4.6	4.0	3.3	3.2
	(°F)	(8.3)	(7.1)	(6.0)	(5.7)
400	°C	5.0	4.6	4.2	3.7
	(°F)	(9.0)	(8.3)	(7.5)	(6.7)
772	°C	5.2	5.2	4.8	4.4
	(°F)	(9.4)	(9.3)	(8.7)	(7.9)

NOTE: To convert degrees Fahrenheit to degrees Celsius: (T_f - 32)/1.8.
To convert degrees Celsius to degrees Fahrenheit: 1.8T_c + 32.
NOTE: 'R' denotes resistance; "Att" denotes attenuation.

Table D-II lists the temperature change that will produce 1 percent change in attenuation.

TABLE D-II. Temperature change required for 1 percent change in attenuation,

FREQUENCY (kHz)		19 AWG	22 AWG	24 AWG	26 AWG
10	°C	3.3	3.9	4.3	4.6
	(°F)	(6.0)	(7.0)	(7.8)	(8.3)
50	°C	3.3	3.0	3.1	3.4
	(°F)	(5.9)	(5.4)	(5.6)	(6.1)
100	°C	3.9	3.3	3.0	3.1
	(°F)	(7.0)	(5.9)	(5.5)	(5.5)
200	°C	4.6	4.0	3.3	3.2
	(°F)	(8.3)	(7.1)	(6.0)	(5.7)
400	°C	5.0	4.6	4.2	3.7
	(°F)	(9.0)	(8.3)	(7.5)	(6.7)
772	°C	5.2	5.2	4.8	4.4
	(°F)	(9.4)	(9.3)	(8.7)	(7.9)

20.3 Simplified attenuation correction. Attenuation varies about 1 percent for every 3.9 °C (7°F) change in temperature. The simplified attenuation correction formula is:

Celsius | Fahrenheit

A_{tc} - A_{20}[1 + 0.0026(7, - 20)3 Atf - A68LI + 0.0014(Tf - 68)3

(Variables are as explained in paragraph 20.2 above.)

30. REPEATER PLANNING LENGTH, COAXIAL CABLE

30.1 Coaxial cable. The repeater planning length at 20 °C (68°F) is calculated by dividing the permitted attenuation between repeaters (a value of 22 dB is often used as the attenuation of the cable per unit length at a design frequency (see table IX, paragraph 5.5).

30.2 Typical planning length calculation. In a typical installation, a grade RG-59/U cable, having an attenuation or 4 dB/100 feet (4 dB/30.5 meter) at 300 megahertz, is used. Amplifiers having a gain of 25 dB (of which 3 dB are allotted for automatic gain control and aging) are used, and a repeater spacing of 22 dB is indicated. The unit length is then multiplied by the quotient 22/4 = 5.5, obtaining an average spacing between repeaters of 5.5 x 100 = 550 ft (167.7 m).

30.3 Temperature correction, coaxial cable. The section planning length, at mean annual buried temperature T, other than 20 ^{o}C (68^{o}F) is calculated from the following formulas:

Planning length in meters = $L[1 + 0.0021(20 - T_c)]$

Planning length in feet = $L[1 + 0.00117(68 - T_f)]$

where:

L = planning length, as determined in 30.2 above, in feet or meters

T_c = mean annual buried temperature, degrees Celsius

T_f = mean annual buried temperature, degrees Fahrenheit

Attenuation increases with temperature because the resistance of conductors and the power factor of the dielectric both increase with temperature, The first formula simply indicates that planning length decreases about 0.2 percent per 1oC temperature increase. The planning length decreases about 0.1 percent per 1oF.

40. ABBREVIATIONS

ac	alternating current
AWG	American Wire Gage
c	Celsius
dB	decibel
dc	direct current
F	Fahrenheit
kHz	kilohertz
m	meter

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APPENDIX E

COMPARISON OF WIRE GAGE DIAMETERS

CONTENTS

TABLE

APPENDIX E

COMPARISON OF WIRE GAGE DIAMETERS

10. GENERAL

10.1 Scope. The size of wire may be designated either by gage number or by its diameter. The size of a solid wire refers to the cross section of the wire perpendicular to its length. The size or gage number of a stranded wire refers to its total cross section. Other dimensions describing wire sizes are circular mils (unit equal to the area of a circle whose diameter is one mil) or square millimeters (mm^2).

10.2 Application. This appendix is a nonmandatory part of this standard.

10.3 Types of wire gages (See table E-I.)

a. American Wire Gage (AWG) is the most common copper wire gage used in the United States. AWG is also known as Brown and Sharp (B&S) Wire Gage. It is the only gage whose successive sizes are determined by mathematical law.

b. British Standard Wire Gage (SWG) is also known as New British Standard (NBS), the English Legal Standard, and Imperial Wire Gage (IWG). SWG is the legal standard of Great Britain for all wires.

c. Birmingham Wire Gage (BWG), although nearly obsolete, is used in the United States to designate the size of brass wire but is used rarely in Great Britain. It is sometimes called Stubs' (Iron) Wire Gage; not to be confused with Stubs' Steel Gage, which has limited use for tool steel wire and drill rods.

TABLE E-I. Comparison of wire gage diameters .

GAGE NO.	AMERICAN WIRE GAGE (AWG)		NEW BRITISH STANDARD (NBS) (OR BRITISH STANDARD (SWG)) WIRE GAGE		BIRMINGHAM (BWG) (OR STUBS' IRON) WIRE GAGE	
	(mm)	(mils)	(mm)	(mils)	(mm)	(mils)
7-0	---	---	12.7	500.0	---	---
6-0	---	---	11.8	464.0	---	---
5-0	---	---	11.0	432.0	---	---
4-0	11.68	460.0	10.2	400.0	11.5	454.0
3-0	10.41	410.0	9.4	372.0	10.8	425.0
2-0	9.27	365.0	8.8	348.0	9.7	380.0
0	8.25	324.9	8.23	324.0	8.6	340.0
1	7.35	289.3	7.62	300.0	7.6	300.0
2	6.54	257.6	7.01	276.0	7.2	284.0
3	5.83	229.4	6.40	252.0	6.6	259.0
4	5.19	204.3	5.89	232.0	6.0	238.0
5	4.62	181.9	5.39	212.0	5.6	220.0
6	4.12	162.0	4.88	192.0	5.2	203.0
7	3.66	144.3	4.47	176.0	4.6	180.0
8	3.27	128.8	4.06	160.0	4.2	165.0
9	2.91	114.4	3.66	144.0	3.76	148.0
10	2.59	101.9	3.25	128.0	3.40	134.0
11	2.30	90.7	2.95	116.0	3.05	120.0
12	2.05	80.8	2.64	104.0	2.77	109.0
13	1.83	72.0	2.34	92.0	2.41	95.0
14	1.63	64.1	2.03	80.0	2.11	83.0
15	1.45	57.1	1.83	72.0	1.83	72.0
16	1.29	50.8	1.63	64.0	1.65	65.0
17	1.15	45.3	1.42	56.0	1.47	58.0
18	1.02	40.3	1.22	48.0	1.24	49.0
19	0.91	35.9	1.02	40.0	1.07	42.0
20	0.81	32.0	0.91	36.0	0.89	35.0
21	0.72	28.5	0.81	32.0	0.81	32.0
22	0.65	25.4	0.71	28.0	0.71	28.0
23	0.57	22.6	0.61	24.0	0.64	25.0
24	0.51	20.1	0.56	22.0	0.56	22.0
25	0.45	17.9	0.51	20.0	0.51	20.0
26	0.40	15.9	0.46	18.0	0.46	18.0
27	0.36	14.2	0.42	16.4	0.41	16.0
28	0.32	12.6	0.38	14.8	0.36	14.0
29	0.29	11.3	0.345	13.6	0.330	13.0
30	0.25	10.0	0.315	12.4	0.305	12.0
31	0.23	8.9	0.295	11.6	0.254	10.0
32	0.20	8.0	0.274	10.8	0.229	9.0
33	0.18	7.1	0.254	10.0	0.203	8.0
34	0.16	6.3	0.234	9.2	0.178	7.0
35	0.14	5.6	0.213	8.4	0.127	5.0
36	0.13	5.0	0.193	7.6	0.102	4.0
37	0.11	4.5	0.173	6.8	----	----
38	0.10	4.0	0.152	6.0	----	----
39	0.09	3.5	0.132	5.2	----	----
40	0.08	3.1	0.122	4.8	----	----

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